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Vegetation mapping in Western Australia

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Abstract

Interest in conservation and wildlife management has increased the value of vegetation mapping as a form of resource inventory. Western Australia achieved an early lead in this field with the work of Diels (1906) and Jutson (1914) but thereafter initiative passed to the eastern States for a number of years until the establishment of a State-wide vegetation survey in Western Australia in 1964. The aims, objects and methods of this survey are described and its achievements in publication are listed.

Introduction

There are basically two different ways in which a field botanist can regard the plant cover of an area in which he is working. He can see it as composed of individual plant species, each to be named and classified, or he can see it in the mass as vegetation having properties of structure and life-form. The former is the taxonomist's viewpoint, the latter the biogeographer's. In the latter case the existence of species is always of interest but it is not the prime interest. Some biogeographers are interested in species as units of association studying their occurrence and relative abundance in different habitats, but others to whom the physiognomy of vegetation is the dominant interest may regard species as no more than incidental. Studies of vegetation are normally accompanied by mapping of vegetation units so that location and extent as well as physical characteristics may be documented, and as techniques of mapping have improved so has vegetation mapping grown as an art and a science.

A vegetation map may be defined as one which shows the nature of the earth's plant cover. Sometimes this cover is a natural one, unmodified by human action, as we still find today in the unsettled inland areas of the State, and sometimes it has been entirely created by man, as in intensive agricultural areas. In intermediate cases, for example, those parts of Western Australia that are under pastoral leases, there is a natural plant cover that has been or is being modified by man and his domestic animals. A vegetation map records what is there but in general crop mapping in agricultural areas is commonly regarded as a separate field, i.e. land-use mapping, while a vegetation map in the strict sense is expected to show natural plant cover as it exists or used to exist. In settled areas there is often an attempt to reconstruct a picture of the original or primaeval plant cover.

The data presented in vegetation maps may be interpreted in many ways and for many different purposes, including the following:—

Conservation: Vegetation mapping provides an inventory of plant communities and plant habitats, which is the basic information required for planning an adequate system of biological reserves. At a later stage a vegetation map of a flora and/or fauna reserve or national park is one of the basic necessities for planned management and control.

Environmental-impact studies. Facts about vegetation are a part of necessary basic knowledge when assessments of impact upon the environment made by proposed mining and other land development are being made.

Potential land use. A vegetation map is a useful basis for more detailed surveys of land potential for agriculture, pastoral use and forestry, and for soil and geological surveys. It shows height and density of vegetation and may be used as a "going" map for military purposes and for oil and mineral exploration.

Early work in Western Australia

Until quite recently the art of vegetation mapping had been very little practised anywhere in Australia. Difficulties in travel and communication, and lack of accurate topographic base maps were formidable obstacles. Gradually, however, as interest in conservation and wildlife management has grown, interest has grown also in vegetation mapping as a necessary form of resource inventory, and several mapping programmes have been set up, supported by the Interim Council for the Australian Biological Resources Study and by State Governments.

It is a common experience in mapping, whether it be topographic, geological or phytogeographic, that it begins with some rather imprecise sketch-maps usually at large scales made by the pioneers

and proceeds by successive revisions to greater precision at smaller scales. Before the introduction of aerial photography in the 1930s it was virtually impossible to map large areas accurately in detail and any precise vegetation mapping was confined to local studies. Larger areas had inevitably to be covered on a sketch-map basis and involved a large amount of guess-work. L. Diels for example furnished a coloured sketch-map at 1:27 000 000 of the whole continent as the end-papers to his book of 1906 but it cannot have been intended to give more than a general impression of the vegetation. Numerous other small-scale renderings of the vegetation of Australia appeared in atlases and geographies throughout the world, all of them unavoidably imprecise and unreliable.

It is interesting that in the early period Western Australia was well to the fore. Diel's book *Die Pflanzenwelt von West-Australien* (The plant world of Western Australia) published in German in 1906, which included the map mentioned above, was the only comprehensive and authoritative account of any Australian vegetation to be published prior to the first World War. Western Australia also produced the first State map of vegetation, when J. T. Jutson in 1914 produced a sketch map at 1:5 000 000 to accompany his classic work on physiography. The map was published in colour and distinguished nine basic vegetation types, alluding to two more (fringing forests and mangrove woodlands) in the legend. Acknowledgement was given to the Forests Department as the source of the information.

In 1928 the Forests Department reprinted the map with the addition of data contributed by C. A. Gardner on the distribution of the more important species of *Eucalyptus*. This map was again reprinted in 1967, without revision. In the meantime Gardner (1942) had published a general account of the vegetation of the State which included a small black and white map on a scale of 1:25 000 000 and this also was still based on Jutson.

Western Australia's early lead in this field was not maintained and the initiative passed in the 1920s to South Australia where the Botany Department of the University of Adelaide, the Waite Agricultural Research Institute, the CSIRO Division of Soils and the State Departments of Agriculture, Lands and Forests, between them mapped most of the south-eastern part of South Australia in terms of vegetation, or of soils and vegetation, at a considerable range of scales. This activity came to be known as the "Adelaide School" and was inspired by Prof. J. E. Wood of Adelaide who produced an integrated text and map in 1937. Important contributions were later made by Blake (1938) in Queensland and by Beadle (1948) in New South Wales, both of whom succeeded in mapping very extensive areas before aerial photography became available.

The introduction of aerial photography in the 1930s transformed the situation and it became possible to map vegetation accurately and rapidly. In Western Australia after World War II the Forests Department conducted detailed stock-mapping (1:63 360) of the State Forests in the south-west, and the pastoral section of the Department of Lands and Surveys produced a number of pastoral-classification plans at a scale of 1:250 000 in which the plant cover was mapped according to its estimated carrying capacity. Some other mapping was carried out by the CSIRO which conveyed vegetation information without mapping it directly. The CSIRO Division of Land Research published three surveys covering almost the whole of the Kimberley District in the north (Speck *et al.* 1960, 1964; Stewart *et al.* 1970) and another survey (Mabbutt *et al.* 1963) covered a strip typical of mulga country in the Murchison region.

These surveys were not vegetation surveys as such but mapped "land systems"; however, as vegetation is a component of a land system and detailed information was given in the explanatory text, it was possible to reinterpret for vegetation if desired. The same applies to the work of the CSIRO Division of Soils which has published three surveys in the south-west, covering the Margaret-Blackwood River area (Smith (1951), the Swan Coastal Plain (McArthur and Bettenay 1960), and the Merredin area (Bettenay and Hingston 1961). As close correlations were found between vegetation and soil types and notes on vegetation were given in the text, the soil maps could be similarly reinterpreted for vegetation.

A State-wide vegetation survey

Attempts to depict the vegetation of the whole of Australia accurately by drawing upon published sources had been made by Prescott (1931) and by Williams (1955) and these highlighted the serious lack of basic information from Western Australia which was shown to be by far the least known of any of the States. In 1964 it was resolved by Prof. M. J. Webb and the writer to promote a State-wide survey to redress the situation. This project which was called the Vegetation Survey of Western Australia has been carried on since, supported by the Department of Geography at the University of Western Australia where the cartographic work is done, and in the early stages by the King's Park Board, and latterly by the Interim Council for the Australian Biological Resources Study, both of which have provided finance for fieldwork and publication. Three maps have been contributed by the Western Australian Department of Agriculture (Smith 1972, 1973, 1974). Several previous accounts of the aims, objects and methods of the survey have been published (Beard 1966a, 1969, 1975a, Beard and Webb, 1974).

The first decision which has to be made on commencing such a programme is what scale is to be adopted, and here one has to consider the area involved, the man-power and finance available and the duration of the project. Obviously a survey of Lord Howe Island or even Tasmania can be made more intensive than one of Western Australia. It was decided that the 1:1 000 000 scale would be the most generally useful within the limits of feasibility. It has the advantage of being the same scale as the International Map of

the World topographic series, and as a French vegetation map series, the Carte Internationale du Tapis Végétal.

The question of scale is of fundamental importance. For the mapping of a given area, the larger the scale the larger the map and vice-versa. Alternatively, with a given size of map, the larger the scale the smaller the area the map portrays, and vice-versa. A vegetation map of the largest possible conceivable scale would be a diagram of a quadrat on which all the individual plants and their coverage were marked. Such a map inevitably represents a relatively tiny area. For the mapping of more extensive areas, the scale has to be reduced. It then becomes impossible to represent individual plants, and they have to be grouped into communities whose boundaries are mapped. At progressively smaller scales fewer communities can be represented and there has to be progressive generalisation of the map.

It therefore follows that for the vegetation mapper there can be no absolute concept of the plant community. The concept is dictated by the scale he is using and the ability to represent units on the map. To give concrete examples, the vegetation maps of Lord Howe Island (Pickard 1974) which covers 13 km^2, of Tasmania (Jackson 1965) covering 42 450 km^2, and of the Murchison Region of Western Australia (Beard 1976) about 385 000 km^2, represent units of quite a different order from one another, because of the progressive generalisation which is obligatory with increasing scale.

It follows also that there can never be any absolute standard for an inventory of plant communities of Australia since the number of communities is dependent upon the scale at which they are being considered.

Having made a general decision on the use of the 1:1 000 000 scale for principal publication, a special series of seven map sheets was designed in order to cover the State in the most economical manner (Fig. 1). The standard grid of the International Map of the World Series (also known in Australia as the Aeronautical Series) necessitates 14 sheets for Western Australia of which five straddle the eastern border and are only half within the State. The special series however is still built upon the standard grid of the smaller 1:250 000 series, shown as smaller rectangles in Figure 1. Basic mapping is done on aerial photomosaics at a scale of 1:63 360 rather than on individual aerial photographs because the latter would be too time-consuming. Adequate detail for the publication scale is obtained from the mosaics and is first reduced and drawn at 1:250 000, then reduced again and compiled at 1:1 000 000. The original 1:250 000 sheets are hand-drawn on film and are filed in the map library of the Department of Geography at the University of Western Australia. Dyeline prints can be obtained on request. Those of the 1:250 000 sheets covering the South-West Botanical Province where vegetation patterns show finer detail and where there is likely to be greater public interest, are being drawn on a standard topographic base and published as a separate series (Fig. 1.)

Classification and terminology

Having regard to the nature of this survey which was essentially a preliminary survey of a very large, little-known area, it was considered the most appropriate to approach the characterisation of vegetation on a physiognomic basis (Beard 1973c). Time would not permit the use of quantitative or phytosociological methods at this stage, however desirable they might be, and it was expected that they would be applied in later, more detailed, work. The broad principles of classification adopted in this survey, therefore, are those stated by Beard (1944, 1955). The basic unit is a floristic unit, the plant association. The association is the largest possible group with consistent plant dominants, either of the same or closely allied species. Associations may be divided into minor floristic groups and may be grouped floristically into alliances. Associations may also be grouped together, according to their physiognomy (structure and growth-form), into formations. The formation is thus a physiognomic unit.

Prior to 1964 the physiognomy, classification and nomenclature of Australian plant formations had been discussed by Beadle and Costin (1952) and by Williams (1955) but there was no generally agreed system. Many advantages seemed to be offered by the approach suggested by Küchler (1949) who drew up a number of simple life-form classes.

Küchler's system had the added advantage that it could be expressed as a mapping notation. It is not desirable that a map should depend entirely on its colours to distinguish units, as the eye may not readily differentiate between all of them, and in any case many of the maps have been published in black and white. The geologists employ a notation of this sort e.g. Tep= Tertiary, Eocene, Plantagenet Group, Ag=Archaean granite. Vegetation units can be simply numbered but this is rather a crude approach.

The trouble was that Küchler's system, while a brilliant idea, included illogical features and was framed to suit North American conditions. Dansereau (1951) reshaped the system into an elegant and logical classification capable of describing any vegetation community in the world. Unfortunately, the mapping notation became too unwieldy to put onto a map! A simpler system was therefore devised for practical use, which has come to be known as the Beard-Webb system (Beard and Webb 1974). It was felt that the notation should be of reasonable brevity and should convey the diagnostic features of the vegetation which are: 1, Nature and size of the dominant stratum and of other strata if of diagnostic importance; 2, Dominant or diagnostic plant species and 3, Density of the strata referred to in (1).

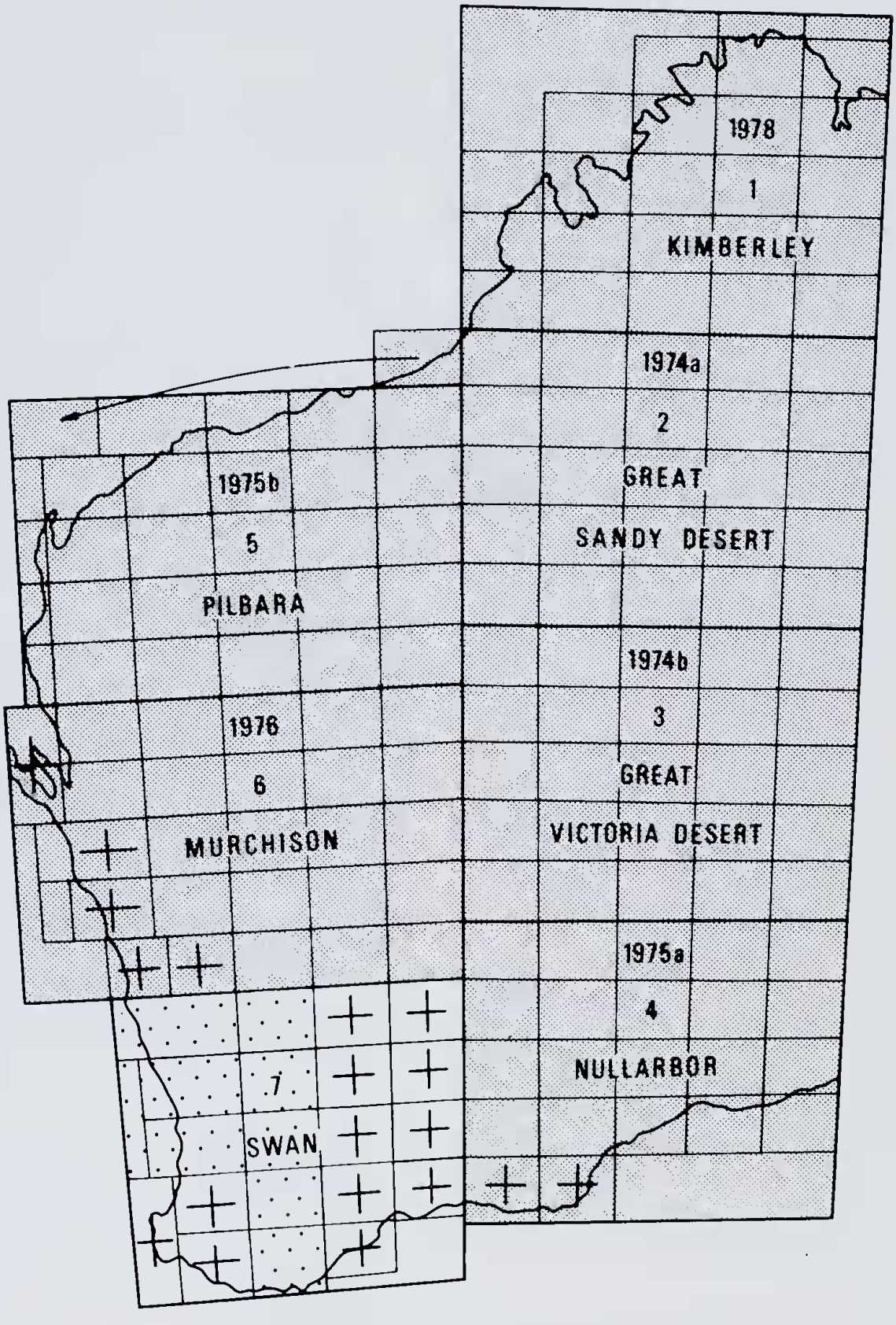

Figure 1.—Vegetation survey; progress in mapping and publication.

The Beard-Webb system is built up as follows:

(1) Physiognomy of dominant stratum (capital letters)—
- T Tall trees > 30 m tall.
- M Medium trees — 10-30 m tall.
- L Low trees < 10 m tall.
- S Shrubs > 1 m tall.
- Z Dwarf shrubs < 1 m tall.
- G Bunch grasses.
- H Hummock grass (spinifex).
- F Forbs.
- X Lichens and mosses.
- C Succulents.

(2) Floristic (lower case letters)—
- e Eucalyptus.
- a Acacia.
- t Triodia.
- x Heterogeneous (mixed or other).

(3) Density (lower case letters)—
- d Dense canopy. Projective foliage cover, > 70 per cent.
- c Mid-dense canopy. Projective foliage cover, 30-70 per cent.
- i Incomplete canopy, open not touching. Projective foliage cover, 10-30 per cent.
- r Rare but conspicuous. Projective foliage cover, < 10 per cent.
- b Barren, vegetation largely absent. Projective foliage cover negligible.
- p Scattered groups. No definite foliage cover.

The letter "C" has been introduced to the classification and defined as "succulents". Most of these are Chenopodiaceae, hence the letter "C", "S" being pre-occupied. In addition to the fully succulent samphires, this class is intended to include the semi-succulent saltbush and bluebush vegetation, which is locally very widespread in parts of the Australian Eremaea, as it is considered essential that these communities be recognized to have a unique character of their own, and differentiated from sclerophyll shrublands. The floristic component (e, a, t, etc.) can be differentiated as e_1, e_2 to indicate particular species, and other letters may be added as required, e.g. m. for Melaleuca.

The actual formulae are to be written with the floristic category first e.g. eMc, aLi: meaning respectively a eucalypt-dominated closed medium tree community (a eucalypt forest in fact) and an acacia-dominated woodland (mulga). The formulae are designed in this "triangular" form in order to be more readily comprehended at a glance. The central capital letter conveys the most important feature (physiognomy), the left-hand one floristics and the right-hand one density.

The principal, capital-lettered category is based upon Küchler's Group 1 Height, and is intended to accord mention primarily to the dominant stratum, e.g. eMc. If two or more strata are considered co-dominant, their symbols may be written together e.g. xSZc. Any diagnostically important strata may be included in this manner—eLr, aSr, pHi.

The floristic category serves to name the species or genera which are dominant or diagnostic, but as most West Australian communities are of simple composition or even single-dominant associations, this category will also to a large extent convey—from the known morphology of the species—a growth-form characteristic of the community. A category "heterogeneous" is provided for mixed communities in which no definite dominance asserts itself.

The third category, density, is the same as Küchler's Group II. Küchler's Group III is not directly included: the characters which it deals with will have been already incorporated in the formula if important i.e. if they are "salient features" otherwise they are disregarded. Dansereau has set up three other categories in his system: function, leaf shape and size, and leaf texture. All of these will be found to be conveyed by the floristic category and are therefore not separately required.

Specht's projective-foliage-cover classes have been introduced and related to the code letters, with the addition of a letter "d" for "Dense" not appearing in Küchler or in Beard (1969). It is intended in Australian work that "d" should apply to rain forests while "c" will be used for eucalypt forests which admit much more light even though tree crowns may be touching.

An attempt is being made to carry the treatment in the notation and terminology through into the map colour scheme. A colour spectrum ranging from blue for moist forest through to red for desert is in accord with general international practice and has been planned as follows:

- T Blue
- M Green
- L Orange
- S Yellow
- Z Grey
- G Olive
- H Red
- F Rare, not provided
- X Hachured
- C Brown

Density of the vegetation is conveyed by shade of colour, dark for dense, pale for open. The general transition from the desert southwards is expressed in the sequence of colours red-orange-yellow-green-blue, and northwards in red-yellow-olive-green. "Z" and "C" are mainly edaphically controlled and are therefore extraneous to the climatic sequence. Considerations of map design are involved at this stage and the colour sequences are designed to be aesthetically pleasing.

Table 1 shows the Beard-Webb classification with its associated nomenclature. It differs from the rather similar treatment of Specht (1970) in basing the classification upon the dominant stratum, not the tallest one, and is more in accord with ecological principles as well as being more suited to mapping. The second part of the table provides for wooded grass and shrub communities which have more than one significant layer. Grassland nomenclature follows Beard (1966b).

Table 1

Nomenclature of vegetation units as used in the vegetation survey of Western Australia

A. Communities with a single significant layer

Life Form/Height Class	Cover of dominant stratum				
	Dense d 70–100%	Mid-dense c 30–70%	Incomplete i 10–30%	Sparse r <10%	Very Sparse b Negligible
T Tall trees >30 m	Dense Tall Forest	Tall Forest	Tall Woodland	Open Tall Woodland	....
M Medium trees 10–30 m	Dense Forest	Forest	Woodland	Open Woodland	....
L Low trees <10 m	Dense Low Forest	Low Forest	Low Woodland	Open Low Woodland	Sparse Low Woodland
S Shrubs >1 m	Dense Thicket	Thicket	Scrub	Open Scrub	Sparse Scrub
Z Dwarf shrubs <1 m	Dense Heath	Heath	Dwarf Scrub	Open Dwarf Scrub	Sparse Dwarf Scrub
G Bunch Grasses	Dense Grassland	Mid-dense Grassland	Grassland	Open Grassland	Sparse Grassland
H Hummock grasses	....	....	Hummock grassland	Open Hummock grassland	Sparse Hummock Grassland
F Forbs	Dense Herbfield	Mid-dense Herbfield	Herbfield	Open Herbfield	Sparse Herbfield
X Lichens and mosses	....	....	Mat Plants	Open Mat Plants	Sparse Mat Plants
C Succulents	....	....	Succulent Steppe	Open Succulent Steppe	Sparse Succulent Steppe

B. Communities with more than one significant layer

Description	Cover of tree/shrub layer			
	Incomplete i 10–30%	Sparse r <10%	Very Sparse b Negligible	Absent
Wooded Bunch Grassland	Savanna Woodland	Tree Savanna Shrub Savanna	Sparse Tree Savanna Sparse Shrub Savanna	Grass Savanna
Wooded Hummock Grassland	Steppe Woodland	Tree Steppe Shrub Steppe	Sparse Tree Steppe Sparse Shrub Steppe	Grass Steppe
Wooded Succulent Steppe	Thickly Wooded Succulent Steppe	Lightly Wooded Succulent Steppe	Sparsely Wooded Succulent Steppe	Succulent Steppe
Heath with Trees	....	Tree heath	....	....
Heath with shrubs	....	Scrub heath	....	....
Heath with mallee	....	Mallee health	....	....

Progress of publication by the Vegetation Survey of Western Australia up to the time of writing (August 1978) is summarised in Figure 1. Five of the seven 1:1 000 000 map sheets have been published (Beard 1974, 1975b,c, 1976a, Beard and Webb 1974) and all but eight of the 1:250 000 map sheets are available (Beard 1969, 1972 a-e, 1973 a, b, 1976 b-f, Smith 1972, 1973, 1974). The survey is thus almost complete and has lifted Western Australia from the position of least to best documented of the States in terms of vegetation.

Future work

It is considered a desirable objective that coverage of Australia at the 1:1 000 000 scale should be completed as soon as possible. Tasmania was done in 1965 (Jackson 1965). State vegetation mapping projects have been commenced at the National Herbarium, Sydney, and at the Queensland Herbarium, but results have not yet been published. It is also a desirable objective that the mapping should be uniform. The authorities conducting geological surveys in Australia long ago decided to adopt uniform mapping standards for the general 1:250 000 series so that maps of any State are comparable. The questions of scale come up again here, however. The standards of the vegetation survey of Western Australia, the Beard-Webb classification system, the related map colours and so on, apply to the 1:1 000 000 and 1:250 000 scales for which they were devised. Uniformity at other scales is not suggested at this stage. Carnahan's (1976) map of Australia at 1:6 000 000, used a modified system based upon Beard-Webb, but changed to suit the requirements of his scale. More intensive, larger-scale, work would also have to set its own standards. This can already be seen happening in the work of B. G. Muir (1977) in the Western Australian Museum's "Biological Survey of the W.A. Wheatbelt", where the Beard-Webb system was expanded by the introduction of several new Life-Form-Height classes to provide for a more intensive definition of stratification. Thus Low Trees have been divided into two, LA 5 to 15 m tall, and LB

< 5 m; a class for the mallee life-form has been introduced and given the letter K, divided into both tree and shrub forms; shrubs are divided into five height classes, bunch grasses into two, while additional classes have been introduced for mat plants (M), herbaceous species (J), sedges (V) and cryptogams (X).

This development is regarded as both logical and welcome: it was always envisaged that something of this kind should and would take place when others came to hang more intensive work within the framework of the extensive survey. It serves to emphasise the point that scale dictates procedure.

Some other large-scale mapping has been carried out recently in Western Australia mainly for biological surveys and should be mentioned, e.g. Beard 1967, 1976g, McKenzie, Burbidge and Marchant 1973, Dames and Moore, 1975, Smith 1977. A small-scale map of the State at 1:10 000 000 has been prepared by reduction of the 1:1 000 000 sheets, recognising 25 basic vegetation units (Beard 1979a).

Derived benefits of the vegetation survey

Vegetation mapping was used for a study of palaeodrainage in the arid zone of the State, in which a map showing the approximate courses and directions of rivers which must have existed in more pluvial times was produced, Beard 1973d). The general accuracy of the interpretation has been confirmed by later work (van de Graaff *et al.* 1977).

Vegetation mapping has also been used to define phytogeographic natural regions in the State. Diels (1906) in treating Western Australia south of the tropic divided the area into two Botanical Provinces, the South-West Province and the Eremaean Province, and subdivided the former into 6 Botanical Districts, the latter (as far as known to him) into 2. Gardner (1942) added the concept of a Northern Botanical Province in the tropics. He later expanded Diel's Botanical Districts on a State-wide basis (Gardner and Bennetts 1956) so that there were now 5 districts in the Northern Province, 5 in the Eremaean, and 6 in the South-West. Burbidge (1960) incorporated the Botanical Provinces into Australia-wide Floristic Zones, and treated the Coolgardie Botanical District as an Interzone or ecotonal region lying between the Eremaean and South-West Provinces.

When vegetation mapping commenced it quickly became apparent that natural regionalisations were present in the grouping of vegetation units and were expressed by the map colours. To a very large degree these coincided with the intuitive ideas of Diels and Gardner and the mapping was therefore used as a means of laying down precise boundaries for the Botanical Provinces and Districts previously rather arbitrarily sketched on a small scale. The regional boundaries have been marked on the vegetation maps, and a new State-wide small-scale map has recently been produced (Beard 1979b).

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